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I. *Magnetical Observations and Experiments; by
Servington Savery, Esq; of Shilston.*

P R E C O G N I T A.

I. **T**HAT which I call the Magnetical Line, is the Position of a Dipping-Needle when it ceaseth from oscillating, and is at Rest in the magnetical Meridian of the Place.

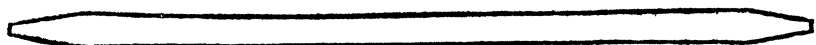
II. By the Word Magnet (unless distinguished) I would be understood to mean not a Loadstone only, but either that, or Iron or Steel, when they have permanent Polarity, or any thing else (if to be found) which has a sensible magnetical or polar Attraction.

III. Of the magnetical Needle, I always call that the North End which (if hung horizontally) naturally turns to the North, and that the South End which turns to the South: But when I use the Words Pole of a Needle, I call that the North Pole thereof which turns to the South, and that the South Pole of it which turns to the North.

IV. Of Touched Iron or Steel (or of Untouched, so long as it remains in a Posture which gives it Polarity) as well as of the Loadstone itself, I call that the North Pole which attracts the North End (*i. e.*) the South Pole of the Needle, and that the South Pole which attracts the South End, or North Pole of the Needle: Or in other Words, I call that the North Pole, in all Sorts of Magnets, which is endued with the same kind of Vertue which the North Pole of the Earth hath, and consequently is repelled thereby: *E contra*, &c.

V. I prepared Nails of several Sizes, from the smallest Sort of Bellows-Nails to the largest Sort of Rafter-Nails, one or two of each Sort, or more of the smaller : I held each of them perpendicularly with its Point upwards, and placing thereon the plain Side of a File horizontally, I filed off a little from the Point thereof (more or less according to the Size of the Nail, perhaps about the Thickness of a Six-pence from a Six-penny one). Then on a plain Hone, held horizontally, I placed the Nail upright, with its Point downward, and so rubbed off the Strokes of the File. Then I rubbed it a little on a Piece of Leather. *Note*, The truer this little narrow Plain is, and more exactly perpendicular to the Nail's Axle, the better.

VI. I prepared Iron Bars of different Lengths after the following Manner : I made each End in the Shape of the lower Frustum of a Pyramid, cut transverse to its Axis about the Middle, or a little higher up. Then I filed the Ends of the Bar as plain and perpendicular to its Axis as I could, and polished them with a Hone, &c. as I did the Nails. *See the Figure.*



VII. One of the Needles I used untouched, for trying Experiments, was made thus : I took some Iron Wire, about the Size of a small Knitting-Needle, and in Length about two Inches and a half. With a Hammer I made it just flat enough in the Middle, to be able to fix the Point of a Punch pointed, to as true a Cone as I could ; its Sides (as I guess) made an Angle with each other at the Vertex of about 45 Gr. or more ; in the Middle of the Wire I punched a Hole at least
half

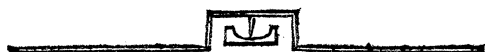
half Way through the Thickness thereof, and wrought the Hole with a Drill (pointed like the Punch) that it might be truly round, and cleansed off the Asperity which the Punch and Drill had raised round the Hole, lest it should injure the Top of the Pin when it was placing thereon. Then I bended it in this Form,



taking Care to bend it the right Way, that the Hole might be on the under Side. Then I marked one End, by flattening it a little with a Hammer, that it might be known from the other. Then placing it on a sharp Pin, to find which End was heaviest, I made both alike in Weight, and deprived it of all fixed Magnetism. Then I brought it again to as true a Poise as I could, by rubbing the heaviest End on a Whetstone, and not a File, which might give it Magnetism again. I fitted a Pin for it of brass Wire, full so small as the middle Strings of a Spinnet, making the Point very meagre and round as well as sharp, and observed it frequently with a Lens of two Inches Focus ; and if it appeared flat, I mended it on a Hone, and took great Care in putting on the Needle, not to hurt the tender Point of the Pin. I put a Glass over it, to keep off all manner of fanning by the Air, the least Degree whereof did spoil the Experiments.

VIII. A second Needle, which I thought better than the former, I made thus : In the middle of such a Piece of Wire as the former was made of, I wrought a Hole through it as perpendicular as I could to its Axis, or Length, and so small as any of those which are drilled through the Pillars of a Watch, if not small-

ler. And having bended the Wire in this Form,



I marked one End thereof, and drove into the Hole a small brass Pin fitted to it; which was very round and sharp at the Point, which rested on a deep Plano-Concave Lens of Glass well polished. (*See the Figure.*) I fitted a Box for it with a Glass over it; which Glass was fastened with a Ring of brass Wire, as the Glasses of Telescopes are; which Ring kept out Air, otherwise had been needful. The Glass Concave was fixed in the great End of a thin Brass Ferule (like that off a Staff) just fit for it, and the small End of the Ferule was fixed in a Hole made for it in the Middle of the Bottom of the Box: I also put a Ring of thin Brass on the Top of the Lens, not only to keep it in steady, but to prevent the Pin from going in betwixt the Lens and the Ferule, which spoils its Point. Doubtless a Concave of Diamond is much better.

Whensoever I used one of either Sort of these Needles (especially for such Experiments as required it to be perfectly void of fixed Polarity) I was obliged to keep it in a Motion either librating up and down like the Beam of a Pair of Scales, or trembling (which is a short pendulous Oscillation from Side to Side) or else both librating and trembling at the same Time; which said two Motions being at right Angles with each other, are not inconsistent: And if the Needle is truly poised, the horizontal Verticity is neither obstructed nor accelerated by the Librations, because they are at right Angles therewith, nor by the Tremblings, because the two Ends perfectly balance one another in contrary Motion.

tion. The Service they do, is to abate that Friction on the Pin's Point, which retards the horizontal Verticity; for when the Friction is divided between the horizontal Verticity, and the Librations or Tremblings (either of the two latter rolling on the Pin more speedily) the far greater Part of the Friction is spent on the Librations, or Tremblings, and consequently there is but little left to retard the horizontal Verticity. I take such a Needle to be far better for my Purpose than the common ones, which have a heavy Socket of Brass, or Steel, in the Middle, useful only to render them portable, but very detrimental in nice Experiments; because the Weight of the Socket not only blunts the Pin sooner, but also encreaseth the Friction, though the same Acuteness of the Pin should be supposed to continue. To renew the Tremblings when they began to abate, I rarely jogged the Box on the Table, for fear of giving it (and the Needle within it) a circular Motion, which obstructs the Design: But I found it best to do it, by jogging the Table gently. When I had Occasion to turn the Needle to any other Point of the Compass, I elevated that Part of the Box which was under one End, until it rested on the Bottom, and in that Posture could turn it as I would; but before I could let down the Box again to an horizontal Position, was forced to wait till the Needle was very still, and to let down the elevated Side easily, and with a direct Motion; otherwise the Needle, as soon as both its Ends were free, would have more or less of an horizontal Motion.

Most

Most of the known Properties of all Sorts of Magnets which have been discovered by the Observations and Experiments of several Persons, including one or two of my own, are the following.

I. THAT the Loadstone, by an invisible Force which differs from that of Gravitation, and also of Electricity, draws unto itself Loadstone, Iron, and Steel; and with the same Kind of Force, or Power, does not (at least very sensibly) attract any other Body whatsoever.

II. That the Loadstone attracts Loadstone, Iron and Steel with a polar Attraction; and that whatsoever Attraction is not polar, is not magnetical.

III. That the two opposite Parts of a Loadstone attract most vigorously, and are called the Poles thereof. The Middle between its two Poles doth not attract at all, and may be called its *Æquinoctial*; and from either Pole to the Middle, the attracting Force does gradually abate.

IV. That in the same, and every Loadstone, the one of its Poles is in Vertue (or rather in Direction) contrary to the other, and therefore they need to be distinguished from each other; which is done by adding North or South. The North-Pole of one Loadstone will not attract, but repel the North Pole of another, though they are possessed of similar directive Vertue; neither will the South Poles of any two Loadstones attract, but mutually repel one another: But the North Pole of one Loadstone, and the South Pole of any other, do mutually attract each other; and though their directive Vertue is contrary, yet the unknown Cause of their Attraction and Repulsion seems to be the same.

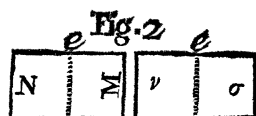
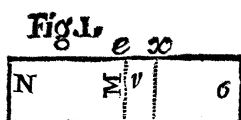
V. That

V. That there is no Difference (at least I could never find it) between the Force or Strength of Attraction and that of Repulsion in the same Pole of any Loadstone or Magnet, unless when a small one approaches so near to a large one, as to have its Polarity more or less diminished thereby.

The preceding Properties convince me, that there is no such thing in Nature as magnetical Attraction without Polarity, which is constituted of Attraction and Repulsion ; and these two Powers being always equally strong in the same Pole of every Magnet, I take it to be a plain Contradiction, to say this or that Loadstone has a strong Attraction, but a weak Polarity or Direction.

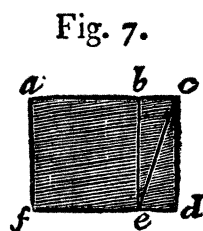
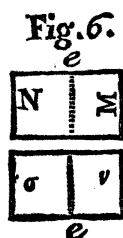
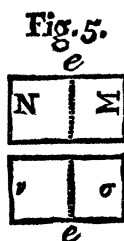
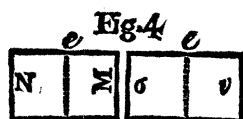
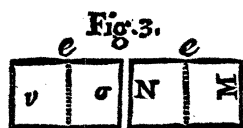
VI. That no interposed Body whatsoever (unless it is magnetical) though the most solid in Nature, was ever known in the least to impede or divert any of the Effects of a Magnet ; but it is always found to attract magnetical Bodies full so powerfully at the same Distance, as if nothing at all was between.

VII. That every Frustum of a Loadstone is an entire or perfect Loadstone, having in itself both Poles as the whole Stone had ; and that the Poles in each Frustum have their Direction (as near as the Figure of it will admit) in the same parallel Line wherein they were directed both in it and the whole Stone, before it was separated therefrom : For the Polarity of every Fragment is usually, if not always (before they are separated) parallel to that of the whole Stone, and consequently to that of each other : And if ever it is found otherwise, I cannot but think that Loadstone wants of Perfection.



Let $N \Sigma \nu \sigma$, *Fig. 1.*, be a Loadstone in the Form of an oblong right-angled Parallelopipedon, whose Polarity is Length-ways, N being its North Pole, e , the pricked Line, its Equinoctial (or Middle betwixt its Poles) where it has no Attraction, and σ its South Pole. Let it be bisected at e , transverse to its Polarity, or Length. Each of its Frusta (represented *Fig. 2.*) when they are placed too remote to act on each other) will infallibly be possessed of both Poles (with its Equinoctial in its Middle) as the whole Stone was before its Bisection: And though originally the one Frustum $N \Sigma$ was all over a North Pole, and the other $\nu \sigma$ all over a South Pole, while they adhered to one another, yet now they are divided, and placed beyond the Reach of each other's Vertue, one half of the Frustum $N \Sigma$ from the Place of its *quondam* Contact Σ , to its Middle e , does instantly become a South Pole, and attract strongly at the Place of Contact aforesaid, which Attraction is gradually less and less until it is abated to nothing at e . So also one half of the Frustum $\nu \sigma$, from the Place of its former Contact ν to its Middle or Equinoctial e , instantly becomes a North Pole (gradually abating in Strength from ν to e) though the whole Frustum, before its Separation from the other, was a South Pole: The Polarity being also directed the same Way in each Frustum that it was in it (and the whole Stone) before

fore the Bissection. The Case also would have been the same, if the Stone had been divided unequally at κ , or elsewhere transverse to its Polarity, *Fig. 1 β* , and of each Fruustum, one half would have been a North Pole, and the other half a South one, with its Equinoctial in the Middle as before. The whole Stone will lift a larger Iron than either Fruustum; but both Frustra, while out of the Reach of one another's Virtue, will each of them lift his Iron, both of which Irons will be heavier than what the whole Stone could lift before it was divided. If the said Frustra are again joined close together at the same Ends which originally adhered, *Fig. 1 β* , being as they stand directed towards each other *Fig. 2d*; or if the opposite Ends of both are joined together, as they stand directed towards each other, *Fig. 3d*, I do not see (provided the



Joint is very good, that there may be a Contact all over it so good as a Workman can make) why they should not compose again one entire Loadstone, so good as it was before it was divided, in all Respects (Allowance being first given for the Waste in sawing it asunder, and mending the Joint) and their joined Poles mutually attracting one another, attract nothing else at the Joint (which being in the Middle, would become

its Equinoctial) but transmitting their Vertue through one another, the Pole Σ of the one Fruustum, *Fig. 2d*, wholly spends itself in strengthening the similar Pole σ of the other Fruustum, by weakning the Pole ν thereof, & *vice versa*. And if their Lengths should be unequal, like the Frustra of *Fig. 1st*, divided at x , the Equinoctial would not be at x , where they were joined together again, but always at e the Middle of their whole conjunct Length, as it useth to be in one entire Loadstone of the same Bigness from Pole to Pole: For I apprehend if any Loadstone should be wrought very Tapering from one Pole to the other, that the Equinoctial could not be precisely in the Middle thereof, but according to what Degree of Taperness it is wrought to, be removed nearer to the great End: But these Things, for want of proper Loadstones, I cannot try, nor yet the following on *Fig. 7th*, which represents a Loadstone in the Form of a Parallelopipedon right angled, in Thickness one Inch, its Breadth af 6 Inches; its Length ac 7 Inches or more, having its Polarity not perfectly length-ways in it, but a little oblique, as the Shade-Lines represent it. If there is cut off from one of it's Ends cd , the Parallelopipedon $b c d e$ one Inch from the said End, it will be one Inch square, and six Inches long: I suppose this lesser Fruustum would have its Polarity changed, and the Direction thereof, instead of running from e somewhat towards d , would run from e towards c in the Diagonal Line ec , or in some Line or other between the Lines eb and ec . I also imagine, that if a Cube was cut off, within a little Time after, from one End, the Polarity therein would be directed as it was therein, while all the said Frustra adhered

togeth-

together; but if the lesser Fruſtum *b c d e* ſhould long remain ſeparated from the whole Stone, before the ſaid Cube was cut off, that the Polarity of the Cube would be more or leſs fixed, and conform itſelf more or leſs to the Direction of the Line *e c*. However, this is certain, that if the two Fruſta are joined together, as they ſtand directed *Fig. 2*, or *Fig. 3*, with the North Pole of one to the South Pole of the other, they aſſiſt one another in liſting Iron. If joined *Fig. 4th* with the South Pole of one againſt the South Pole of the other, by repelling they reciprocally deſtroy each other's Vertue, and alſo hinder one another's Attraction at the North Poles, which are not joined. If they are placed together, as in *Fig. 5th*, though they endeavour to avoid one another, yet they do not deſtroy each other's Vertue ſo much as in the preceding Caſe, nor yet at all if there is a perfect Contact: For if this Poſture of two Magnets actually adhering would diminifh their Vertue, one Part of the ſame Loadſtone would deſtroy another Part of itſelf, and in a very ſhort Time there would be no ſuch Thing as Magnetifm. In this Poſture they mutually help one another's Attraction, becauſe their Polarities are directed the ſame Way. If they are applied, as in *Fig. 6th*, with their Sides together, and their Polarities contrarily directed, the North Pole of the one (at either End) attracting the South Pole of the other, and the South Pole the North, they ſcarcely injure one another's Vertue by ſo lying together, but hinder each other from attracting other Things, by ſpending their Vertue on each other.

VIII. That all magnetical Attraction (as alſo Repulſion) is mutual; for Iron or Steel attract the Loadſtone,

stone, as that does Iron or Steel, and they also one another.

IX. That every Loadstone communicates Vertue to Iron or Steel, not only by Contact, but even by an Approach of them within its attractive Sphere, more or less as nearer to, or farther from its Body; and likewise its Poles, also according to the Shape, Bulk and specifick Vertue thereof, and Figure of the Iron or Steel, and their Proportion of Magnitude to one another. I apprehend, that though a great Magnet (I mean of such as are similar in Figure and specifick Vertue) will lift considerably larger Irons than a small one, yet the small one shall give to the same Piece of Steel (provided it is not too large for it to conquer) well nigh (if not altogether, as to Sense) so strong a Touch as the great one. And I have experienced, that if the small one is specifically pretty much better, it will give the same small Piece of Steel a considerably stronger Touch than the great one can, though the great one is capable of lifting perhaps three or four Times so much as the small one. *Note*, That if the great one is so strong as to give the small Piece of Steel so much Vertue as it is capable of receiving (for there is, I suppose, a *ne plus ultra*) that then should the small Stone be ever so much better, it cannot mend the Touch given by the great one. Some write, that the Loadstone loses none of its Vertue by communicating of it to Iron or Steel, which I somewhat doubt the Truth of, especially if the Stone is small in Proportion to the Steel, in which Case I have known touched Steel lose considerable Vertue.

X. That Steel is not only more receptive, but more retentive of Magnetism than common Iron; Iron or
Steel

Steel hammered hard, than the same while soft ; but Steel hardened by quenching, than either of them. My Observation has been, that Steel cannot be seasoned too hard for Retention (nor, as I think, for Reception) of Magnetism ; but may sometimes warp too crooked for its intended Use, and must be made right again some Way or other, either with a Grinding-Stone, or (if that will not do) by heating it to a blue Colour, and gently hammering it while hot ; but if it can be helped, the Temper for the blue Colour is too soft.

XI. It has been observed, that oblong Pieces of Iron or Steel applied any how to the Loadstone, receive Vertue chiefly (some say only) as to their Lengths. This was what induced me to explain *Fig. 7th*, in the Middle of *Pag. 304*. For I think it a parallel Case with this here, and suppose that the Vertue may incline to run length-ways even in the Loadstone itself. However, I think if it must be allowed to be length-ways, it is sometimes found to be very irregular in pretty long Pieces, as North Pole against North Pole, South Pole against South Pole several Times in the same Piece, which several contrary Polarities have been observed by several in Wires, and I have seen in a round Bar (of which Irregularity, and the Method of curing it, more hereafter) But such contrary Polarities seem unaccountable.

XII. That such Iron and Steel as has magnetick Vertue communicated to it, does also communicate thereof to other Iron or Steel after the same Manner a Loadstone does. Which Vertue, after never so many Communications, is, as to its Nature, perfectly the same with that of the Stone itself, having both Poles,
and

and will touch other Steel, and that a Compass, so well as the Loadstone itself, and so vigorous, if used as hereafter is directed.

XIII. That the Earth contains within it, at or near its Center, a Loadstone or Magnet (probably spherical) large enough very sensibly to affect magnetical Bodies all over the Surface of the Earth. The Poles of its Attraction are considerably distant from those of its own, which are the same with those of the Earth's Diurnal Rotation. This internal Magnet must either be loose from the Body of the Earth, and revolve within it very little slower, or else, if it is fixed to the Earth, the very Polarity itself must have changed its Situation in respect of the said Magnet, One, of which, several recorded Observations in distant Years sufficiently prove. The former seems most probable: However, I imagine (was it not for the Charge and Trouble) an Experiment might be made which would shew whether or no it is possible in Nature for the Poles of the said Central Magnet to change their Situation in respect of itself, as well as of the Earth, as will appear when I give the Description of it.

XIV. That every Loadstone within its attractive Sphere has a Power (the nearer either of its Poles the greater) to keep one Piece of Iron suspended to another, especially if that to which it is suspended is the largest, and their Ends be bright and clean, where they touch one another; and if the suspended Iron is not too heavy, the other will draw it up from either Pole of the naked Loadstone actually touching it, and will also keep it suspended, till at a considerable Distance therefrom; but will not draw it off in
such

such manner from the Armour of unarmed Stone, if the Armour and Iron are both of them bright and clean at their Contact. Hence it must follow,

XV. That an armed Loadstone can lift more with either of its Poles, used singly, than the same can lift naked; and this it will do, though the Armour should be narrow, and touch very little of the Stone; how much more then will it lift, when the plated Part thereof covers all the End of the Stone, and secures all the Vertue of that Pole to which it is applied, leading it to the other End which attracts? I take soft Iron to be so good for Armour as the choicest Steel, if not better.

XVI. That not only Steel or Iron regularly touched, but also oblong Iron void of permanent Vertue (so long as it has a transient Vertue by Position of either of its Ends towards the Pole of a Loadstone large enough to affect it at a considerable Distance) will perform all that any Loadstone can, though not with the same Degree of Power: For either of them will attract, keep one Piece of Iron suspended to another, and communicate some Degree of permanent Polarity to Steel well hardened, as I have experienced, and also to an Iron Wire.

XVII. That the Earth's central Loadstone, or Magnet, has all the same Vertues which others have, and no discovered ones besides; and though we cannot approach it, yet it acts as others do at a proportionable Distance. I have experienced, that it will keep a prepared Six-penny (or with more Difficulty a Ten-penny) Nail suspended to a prepared Iron Bar about $\frac{2}{8}$ of an Inch square, and 5 or 6 Feet long, in an erect Posture with either of its Ends downwards. I hung up the Bar in a Room
by

by a Loop of small Cord fastened at the End which was upwards ; I then carefully wiped the lower End of the Bar, and the Point of the Nail, that there might be no Dust, or Moisture, to prevent a good Contact, taking Care not to touch either of them with my Finger, lest Perspiration should sully them. Then holding the Nail under the Bar very erect, with its Point upwards, I kept it close to the Bar, by only one Finger held under the Head of it, for the Space of 30 or 40 Seconds or more. Then I withdrew my Finger very gently, and directly downwards, that the Nail might not oscillate ; and if it fell off, I wiped its Point as before, and tried it again at some other Part of the Plain at the Bottom of the Bar ; for I always found it would more readily hang at one Place than another, and usually the Middle was not so well as towards one of the Edges or Corners, and the Success better nigh one Edge or Corner than another. If both Ends of the Bar are equal in Bigness, and the Preparation of their Ends similar, it is indifferent which End is downward, if it has no permanent Vertue : But if it has no more than an inchoate or imperfect Degree of fixed Polarity, one End will answer better, and the other worse, in Proportion to the Degree of imperfect Polarity which it has.

XVIII. That of a soft Iron Bar void of fixed Polarity, so soon as it is in an erect Position, the higher Part from the Middle upward becomes a North Pole in North, or a South Pole in South magnetick Latitude. And, *e contra*, the lower Part from the Middle downward becomes a South Pole in North, and a North Pole in South Latitude : But so soon as ever the Bar is inverted, the Polarity will be shifted in it,
and

and in North Latitude the End newly placed upward becomes the North Pole, though it was a South one immediately before, and the other End the South Pole, though it was its North one just before. The Case is the same, if such a Bar is placed horizontally in or near the magnetical Meridian; for the End directed toward the North will constantly be a South Pole, and that which is directed toward the South, a North one; and so soon as ever the Ends of the Bar are shifted, the Polarity, in respect of the Bar, is shifted also (but not in respect of the Earth) for which Reason this Vertue is called Transient, and is communicated by the Earth's central Magnet in such Manner as other Loadstones are said to do, *Page 309th, Prop. 16th.*

XIX. Since in North Latitude the North Pole of the Earth's central Magnet not only gives the Vertue of a South Pole to that End of a Bar which is nearest to it, but also helps it to lift Iron when neither the Bar nor Iron lifted has any permanent Vertue; the said Magnet must therefore necessarily help the South Pole of any Loadstone or Touched Steel in lifting Iron, but hinder its North Pole. This agrees with common Experience, the North Pole of a Magnet being unable to lift so much as its South one in North Latitude, but more in South Latitude.

XX. The preceding plainly shews the Reason why an armed Magnet, when both of its Poles are applied to a Piece of Iron, will lift several times so much as with either Pole single. For the North Pole of the Magnet, by sending its Vertue through the attracted Iron, powerfully helps the South Pole of the said Magnet in attracting. Again, the strengthened South Pole

U u

must

must more powerfully increase the Attraction of the North Pole : And since the Poles mutually assist one another's Attraction, with a Power much greater than if they themselves are not assisted, the conjunct Poles must necessarily lift at least twice so much as both of them can lift separately. I once tried, and found the South Pole armed to lift 1125 Grains, and both Poles united 5760 with a little more Difficulty. The Ratio is about 1 to a little more than 5.

XXI. That if a Bar of Iron or Steel (not having the least Degree of fixed Vertue) is placed in any Posture (except at, or near to a right Angle with the magnetical Line) it will not only for the present receive a transient Polarity thereby, but if it so remains long enough, the said Polarity will gradually become fixed or permanent, more or less, according to the Hardness or Softness of the Bar, Time it has remained in that Position, Angle its Length makes with the magnetical Line, and Proportion of the Length thereof to its Bigness, the longest (*cæteris partibus*) usually receiving most Vertue : And sometimes when all these Advantages concur, the Polarity will be sensibly permanent in a little Time, and not require a very long Time to be rendered pretty strong.

XXII. That by placing the said Bar afterwards in the same Position, only with its Ends shifted, it will gradually lose its gained Magnetism, and at length have its Polarity changed.

XXIII. Mr. *Boyle* found one of his Loadstones much impaired by lying long in a wrong Posture ; I suppose he meant a repelling one, with its North Pole towards the North Pole of the Earth. Also by applying one Pole of a very small Piece of Loadstone to the
same

same Pole of a large one, he soon changed the Polarity of the former, but could not effect it on a Piece of any considerable Bigness, though he tried some Hours. I have changed the Polarity of a small Frustrum of Loadstone suddenly, and without a Contact, by holding one of its Poles nigh the same Pole of a Piece of Touched Steel much less than a common Case-Knife, at above $\frac{1}{8}$ of an Inch distant, which would make the Frustrum leap to it. I repeated these Changes frequently with the same Frustrum.

From this, and some of the preceding Experiments, I conclude, that if two paralleliped Loadstones equal in Magnitude and similar in Substance, Figure and Vertue, are placed close together as in *Fig. the 4th*, with the North Pole of the one directed against the same Pole of the other, or with the South Pole of the one against the South Pole of the other, and the Direction of their Polarities magnetically East and West, they will by Repulsion (as it were in a Duel) reciprocally destroy one another in an equal, though long Time: But if they are placed (in the same Situation in respect of one another, *viz.* North Pole against North Pole, or South Pole against South Pole) with the Direction of their Polarities in or near to the magnetical Line, that Stone (in North Latitude) whose South Pole stands directed to, or pretty much towards the attractive Point of the Earth's central Magnet receiving Assistance therefrom, will not lose Vertue so fast as the other, and consequently never lose all its Vertue till it has perfectly destroyed the Polarity of its Antagonist, which it will do in less Time, and afterward give it some Polarity again contrary to what it had at first.

XXIV. That Magnetism not only in touched Iron and Steel, but also in the Loadstone itself, is soon destroyed by Fire.

XXV. That though Fire destroys fixed Magnetism in Steel or Iron, yet if they are set to cool in an erect Posture, or rather in the Direction of the magnetical Line, they will gain more or less fixed Vertue by the Time they are cold; but especially Steel heated to a seasoning Height, and in that Position cooled suddenly under Water, which I have found to fix its Polarity so thoroughly, as that with its North Pole held downward, it would attract the North End of a Dial Needle.

XXVI. That while a Piece of Iron of some Magnitude is held at one Pole of a Loadstone, it will increase the Attraction of the other Pole thereof, and enable it to lift somewhat more.

XXVII. That if either Pole of a Magnet large enough, toucheth one End of an oblong Piece of Steel (not too big and long for the Magnet easily to act on) it will transmit its own Vertue to the other End of the Steel which is farthest off, and make it a Pole of its own Kind, whilst the End which touches the Stone has Vertue of the contrary Pole: But the Vertue usually is not so strong in the End which is untouched, as in that which is; though I do not know but in some Time it may gain more, and the other lose some, until the Vertue in each End is nearly equal.

XXVIII. That any Loadstone put into a Dish with its Polarity in an horizontal Situation, and the said Dish, with the Stone in it, put to swim in the Middle of a large Vessel of Water, will turn itself, with the Dish wherein it is, until its South Pole is directed in the Horizon towards the magnetical North Pole of the
central.

central Magnet (by the Force of its Attraction thereof, and Repulsion of the opposite Pole) and there rest after a small Vibration or two.

XXIX. That the Fly of a Compass (because it is a perfect Magnet, *Prop. 12*) if it turns easy on its Pin, must necessarily conform its Poles to the magnetical Meridian as the Loadstone does, and for the same Reason.

XXX. Also because Steel regularly touched is a perfect Magnet, the North Ends of the Flies of several Compasses must all of them repel one another, and so must their South Ends: But the North End of one and the South End of any other, do mutually attract each other, as is said of Loadstones, *Prop. 4th*. And in North Latitude the North End of a Needle will consequently vibrate towards the Top of a transient Bar erected, and the South End towards the Bottom.

XXXI. That a Needle first equally poised, then touched and put to oscillate on its Pivots in the magnetical Meridian, will in North Latitude have its North End (*i. e.* its South Pole) depressed until it directs to the North-attracting Point of the central Magnet; where, after several Oscillations, it will at last rest: And in South Latitude the South End will be depressed after the same Manner.

XXXII. That not only a touched horizontal Needle, which has permanent Polarity, will endeavour to conform itself to the magnetical Meridian, but also one that has no other than transient Vertue, and is with the greatest Care freed from fixed Magnetism (if made and used as in the *Præcogn.*) will do so too, though with this Difference, that which End soever happens to be placed nearest towards the magnetical North will faintly

faintly turn thither ; and if that End is not suffered to remain so too long, then the other End, placed nearest to the North, will turn thither as the first did. In trying this Experiment, I sometimes found, that when the Needle had rested in the Meridian only a few Minutes, it gained a perceptible permanent Vertue, so that its other End would not be attracted to the magnetical North, unless it was placed considerably nearer thereto than I had placed the first End ; and having so stood some Time, lost again the said inchoate Permanency, and received Polarity, the contrary Way. Once, while I dined, and sat but a little Time after, I could not make the End which I left towards the South, to stand towards the North, unless I placed it very true in the Meridian ; so that I was forced to free it again from Magnetism before I could use it to repeat the same, or try the following Experiment ; for the least Fixedness of Polarity in the Needle would more or less obstruct both.

At the magnetical East or West of the Needle's Pin, so nice as I could guess it, I held at a great Distance, either the South Pole of a Loadstone, or lower End (which is the South Pole) of an erected Bar (both of them answered alike) and gradually approached it nearer, in a direct Line, toward the Pin, until it began to attract the Needle, which I observed was as I expected at the South End : I then changed the Ends of the Needle, and gradually approached the South Pole of a Magnet as before, and constantly found it to attract that End which was toward the South ; and the North Pole of the Magnet, after the same manner, would attract the North End of the Needle when it had only transient Vertue.


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I remember, that in my younger Days I once diverted myself with making an horizontal Needle, and a Dial-Box for it, one of my School-fellows having a Load-stone. Before I could have the Use of the Stone, I often held my Needle within its Box, sometimes with its intended South End towards the Bottom of a Window Bar (having lately seen one of my Companions try it with his Pocket Needle, which was touched) and at other Times I would hold the Needle's North End at the Top of the Bar. I observed the Needle, which was hung very tender, to make Vibrations at either End of the Bar. I happened to set it down in the Window at a good Distance therefrom, and found the South End more inclined to vibrate to the Bar's Bottom than the North End, and seeing it to have some Vertue, I thought of encreasing it by taking the Needle out of the Box, and applying it to touch the Bar with its proper Ends. By this Method alone it gained such a Degree of Polarity as would constantly turn its proper End to the North, if it was kept trembling; but if I placed its contrary End to the Bar, the Polarity would be changed presently. By this Way of Management I could give it but a faint Verticity, which was soon more vigorous when I got the Use of the Stone, though it was small, and not of the best, and the Needle soft Iron. And this was all, at that Time, I knew of Magnetism, having never read the particular Properties of the Stone, nor seen one before, nor heard of the untouched Needle's Verticity, or its vibrating to a Bar.

Having within the Space of a few Years past had a fresh Inclination to make some magnetical Experiments,

rinents, amongst other Thoughts the above-mentioned came into my Mind, That Iron, not having any fixed Polarity at all, might (if it moved tenderly enough) conform its Ends to the magnetical Meridian; which at length put me on making such Needles as are described in the Beginning, of which either Sort answered my Expectations abovementioned. Afterwards I touched one of the first Sort of Needles (described *Præcogn. 7th*, whose Length was $2\frac{1}{2}$ Inches, and Weight 36 and *Gr. ij*) on a Piece of transient Iron (made for Armour of a Magnet) which measured in Inches each Side of the broad plated Part about $1\frac{1}{2}$, the parallelo-piped Part in Length 2 , and in Breadth (equal to its Thickness) $\frac{1}{2}$. So its whole Length was full 3 Inches and $\frac{1}{2}$. Its Weight *Troy* was $3\text{ iij } 3\text{ ij}$. This held with its Length directed in the magnetical Line, gave the said Needle Vertue enough to vibrate about four times in one Minute. I held the Needle, while touching, in an horizontal Situation, with its North End directed towards the North, and placing its Middle about the Top of the Iron, drew it along Southward: Likewise placing its Middle about the Bottom of the said Iron, I drew it Northward, that the South End might be touched as well as the North. I afterwards touched it my new Way (hereafter mentioned) with the said Piece of Armour, and a small Piece of transient Iron, which made it vibrate about six times, and I believe it would have made more Vibrations, had the Needle been hardened Steel.

Having no other than a small Loadstone of a very irregular Shape, I was loath to diminish it enough to bring it into a tolerable Figure to receive Armour, but did only grind a little Place plain at each Pole,
where

where I bound it on with Thread when I had ground it. The Weight thereof naked was but 3vij 3ij Gr. vj; its armed South Pole would only lift 3vij 3s Gr. iij, which was a Key. The not knowing where to get a better, made me think of improving what I had. I considered, that since a larger Stone of the same specific Vertue would lift more, it might possibly communicate more Vertue than mine could to the same Piece of Steel, but could not fail of so doing to a much greater Piece; and having observed that touched Steel would communicate some Vertue as well as attract, I got some Steel Wire (the largest in the Shop where I could meet with any) which having cut into equal Pieces, and filed their Ends so transversely as I could, and very plain, I made a Standard with a Plate of Iron, into which I could but just thrust the shortest; and filing all the rest till they would but just enter the said Standard, I reduced them nicely to the same Length. Then having marked one End of each of them with the Edge of a File, I seasoned them very hard, and made them, Ends and all, very bright. Each of them measured in Length about 2.74 Inches, and weighed 36 Grains or more. I weighed one of them, and they were all of the same Piece of Wire, therefore could not differ much in Weight. With my Loadstone I touched 37 of them, one by one, making their marked Ends their South Poles. I laid them Side by Side at about half an Inch Distance from one another on a Board, with their marked Ends toward the same Edge thereof, and took Care that they should not touch one another after they came from the Stone, before they were all of them touched thereon. Then having Thread and Armour made like this  (one Piece marked, which

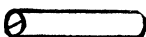
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I applied to the marked Ends of the Wires) in a readiness, I speedily did thrust them together into a Bundle, and casting the Thread 2 or 3 times round them, with my Fingers I formed the Bundle into a regular Hexagon as soon as I could, and then bound them fast from End to End, and bound fast the Armour. I took the Number 37, because that would form a regular Hexagon at each End, and so will also 19 or 7. Finding this artificial Magnet exceed my natural one, I held the Artificial in one Hand, and the Natural in the other, the North Pole of the one against the South Pole of the other, and placing their Armour on the Middle of one of my Wires, drew the Magnets asunder, and so touched both Ends of the Wire at the same Instant. In that manner I touched one by one a second Set of Wires, which I managed like the first, and bound on the Armour of the first Set to the second. The South Pole lifted a Key, Weight *Troy* 3ij 3ij 3ij *Gr.* v. Both Poles united would, with Difficulty, lift the said Key with Weights fastened to it, the whole 1lbj *Troy*. I next tried with 19 Wires, for which I made Armour of a proportionable Size; but that did not answer so well, I thought, as 37, though I repeated the Touch. Afterward I took 7, which I thought performed according to its Quantity as well as the 37. Therefore I ever after used the Number 7.

In the next Place I thought of mending this Way of Touching, by placing all the 7, or more of them, with their marked Ends toward the North in a long small Trench, whose Depth was just fit for one of them, to keep it from rolling away while I was touching it and its Fellows. The North End of one touch-
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ing the South End of the other, and adhering by their magnetick Vertue, I placed the two Magnets, as before, at their conjunct Middle (not letting them remain there a Moment) and then instantly and speedily drew one Magnet to one End of the Wires, and the other Magnet to the other End of them ; by which Method I touched them, as it were, all at once, and as if they had been but one entire long Wire. I found this Way not only more expeditious, but more advantageous, giving all of them a stronger Touch: But the Wire at each End was not so strongly touched as the rest ; therefore I placed more Wires in the Trench than I had Occasion for, and laid aside those at each End, whose Vertue was weaker. One of these Wires, when it was thus newly touched, would lift a prepared Nail 4.75 Inches long, in Weight *Troy* 3vij Gr. vj or vij (*i. e.*) more than 426 Grains. The Weight of the Wire can be had in that of the Nail 11.8 $\frac{1}{2}$ times. I placed all the 7 separately in the magnetical Line for about two Days ; in which Time all of them had lost some Vertue, yet one of them would with Difficulty lift the Nail aforesaid, which it lifted somewhat easier just after the Touch ; and that which had lost most Vertue, would easily lift a Nail of 4 $\frac{1}{2}$ Inches long, in Weight 306 Grains.

Having such Success, I got seven round Bars of Steel to be made, from End to End of one Size, so that they would but just go through a Hole made on Purpose in a Plate of Iron, and tried their Lengths in a Standard as I did the others, and marked one End of each of them with the Corner of a File in this Manner, 

that I might be able to see the Mark when they were bound together, lest either of them should be placed

with its End the wrong Way. Their Diameters were about $\frac{3}{8}$ of an Inch, and their Lengths about $12\frac{1}{4}$ Inches good Measure. I hardned and cleansed them as I did the Wires, but one of them happening to break by a Fall in touching, I got it supplied, and, for Fear of such another Accident, reduced them to almost a blue Colour. I laid them one after another in a Trench planed for them, in a long Piece of Wood about the Depth of half their Diameter, putting their marked Ends all one Way: I made a Hole in the Trench a few Inches from one End of the Piece of Wood, and put a Pin in it to keep the Bars from sliding to the Ground, and elevated the other End till it was, as I guessed, in the magnetical Line. I then touched them with two of my Magnets as before, and this I found the best Way of all. When they were finished, and armed with proper Armour, the North Pole lifted above half a Year after *the Troy*, and the South Pole considerably more. In making one of these, I met with an odd Accident; for after I had begun to touch it, apprehending it was a small Matter bigger than the rest, I attempted to mend it on a Grinding-stone, whose Axes were directed about 14 or 15 Degrees from East towards North, and from West towards South. I was not careful to keep its Poles the proper Way in grinding, but held the Bar sometimes a-cross to the Stone, which would make it jar, at other times, with the North Pole toward the North. Afterward I touched it again with the rest, but could not give it an Attraction equal to that of the others. I happened to try with my Dial-Needle whether the Change of Polarity was in the very Middle of the Bars, or nearer to one End than the other, and in this Bar found several Polarities contrary to my

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Expectation, but how many I am not certain, being several Years since, and I not heeding it nicely. As I held it erect, the Bottom was a South Pole, further up no Attraction, the Pole changing a little higher (I think one third Part of the Bar's Length) a strong North Pole, and about $\frac{2}{3}$ up a strong South Pole, and at the Top a strong North Pole, the Middle between each Pole not attracting. Whether the jarring on the Grinding-stone while held in a wrong Posture was, as I suppose, the Cause of this irregular Vertue, or whether I might at first, by Mistake, touch it the contrary Way, I durst not positively assert; but all my Care and Labour would not help it by touching: For, as the Vertue became stronger in the Ends, so did also the Polarities in the other Parts of the Bar. I was somewhat concerned at this Disappointment, doubting it must have been new seasoned, which would have created the Trouble of cleansing and polishing it the second Time. I thought first that I would try to cure it by putting it over fresh Wood-Coals in an horizontal Posture, with its intended South Pole directed towards the magnetical North, which I did, and so kept it until it was blue. Then I took it out of the Fire, and cooled it in almost the same Posture, for I think the North Pole thereof was elevated. I tried it without re-touching, and found it perfectly cured, the Polarity regular throughout, and (which I was surprized at) attracted full so strongly as either of the rest.

I next endeavoured to procure Magnetism in Steel, without the Assistance of any Magnet (except the Earth's central one.)

Finding

Finding my artificial Magnets, rightly used, would communicate more Vertue to other Steel than they themselves had, and observing that erect Bars had some Vertue from the Earth's Magnet, and having also experienced that Iron, which had only transient Vertue, would, when in an erect Posture, or in the magnetical Line, give a small Degree of fixed Polarity. (*Vide supra, Pag. 317.*)

I ordered nine Steel Bars 0.75 of an Inch square, and 16 Inches long, to be made. Some of them, through the Smith's Fault, were a little less; the Weight of the heaviest was, after it was finished, 3 lb *Avoirdupois*. I made them moderately bright by grinding, and filed their Ends so plain as I could, and transverse to their Lengths, by help of a Carpenter's Square; then marked one End of them, and, when hardened, I scowred them bright, and polished their Ends very well. I fitted a Piece of Armour for each End of one Bar, and marked the Piece which was for the marked End of the Bar, and bound fast both Pieces of Armour to the same Bar, one at each End: Then standing with my Face toward the West, and holding the Palm of my Left Hand upward, I placed therein one of the Bars without Armour with its marked End Northward, and grasped it fast at its Middle, with my Fingers on the West Side, and the Ball of my Thumb on the East Side, where I also laid along my whole Thumb to keep it steady: So the upper Part of the Bar was open from End to End. Thus holding it, I elevated the South End thereof until I guessed it was in the magnetical Line; and holding with my Right Hand the armed Bar, with the Poles of the Armour downward, and the marked End toward the North depressed to the
magnetical

magnetical Line, I placed the Pole of the upper Armour about 4 or 5 Inches from the Top of the unarmed Bar, and so soon as ever it touched the Bar, I began, with the greatest Speed I could make, to draw it downward until I was past the Middle, and from thence to the Bottom gradually slower. When it was at the Bottom I permitted it to rest there about 1 or 2 Seconds. After the same Manner applying the Pole of the lower Armour to the unarmed Bar about 4 or 5 Inches from its Bottom, I drew it upward, speedily at first, slower when above the Middle, letting it rest a little at the Top. Having upwards and downwards alternately repeated the Touch on the same Side of the Bar, I touched the opposite Side thereof, which was next my Hand, in the same Manner, and afterwards the two other Sides. Then holding the unarmed Bar erect, I used to see if it had gained any fixed Polarity by holding my small Needle at the Top and at the Bottom of the Bar; for if it had gained any Vertue by the Touch, it would attract the Needle stronger, at the same Distance, when the marked End of the Bar was held downward, than when it was held upward. If I found it had gained any sensible Vertue, I took off the Armour from the first Bar, and bound it to the second which I had touched, and after the same Manner touched the first Bar with the second, as I had touched the second with the first. And when by Trial with the Compass Needle I found the armed Bar had communicated to the other more Vertue than was in itself, I took off the Armour and bound it to that which was newly touched, and therewith retouched that which I had disarmed. In a few Repetitions of changing the Armour from Bar
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to Bar, and touching the weakest, I procured in both of them (without the Assistance of either of the other seven) a fixed Polarity to such a Degree as that the North Pole, or unmarked End of either of them held downward, would attract the North End of the Needle, though much fainter than if the North Pole of the Bar had been upward, and Position did not now change their Polarities, but only weaken them: Therefore I now call their Vertue perfectly permanent. Four or five Repetitions more encreased their Vertue to such a Degree as that the South Pole of one of them would lift a Ten-penny Nail prepared, and after 2 or 3 Repetitions more a common Door Key of an Iron Box-Lock, Weight *Troy* 3j and above 3ij, not by the Bow, but by its lower End, which was wrought somewhat globular and polished. In the last Place I got a Piece of Inch Deal above three Inches broad and 7 or 8 Feet long, in the Middle whereof, at about 5 or 6 Inches from one End, I made a Hole through with a large Gimlet, into which I drove an Iron or Steel Pin, whose Length (besides what went into the Wood) was a little less than the Thickness of one of the Bars. Then I placed the biggest Bar on the said Board with its marked End close to the Pin, and its Length parallel to that of the Board, and with an Awl made four small Holes in the Board, one of them on each Side of the Bar about an Inch from the Bottom, and about the Thickness of a Sixpence, from its Sides, and the other two after the same Manner, about an Inch from the Top. I drove into them Pins of large Wire half an Inch long, besides what was in the Board. The Pins were to keep the Bars from sliding out of their Places in touching. Then removing that, and placing
any

any other Bar between the said Pins, with its marked End close against the great Pin, I placed the marked End of the said biggest Bar close against the unmarked End of the other, and made four Holes on its Sides, and drove Pins in them as before, and so continued to do, until the Board was full : It held half a Dozen Bars. I took Care to place the marked End of every Bar directed towards the great Iron Pin which was to keep them from sliding down to the Ground, when the other End of the Board was elevated, to stand in the magnetical Line. The Board standing with one End on the Ground, and the other leaning against the Wall, at the South End of the Room, I took the armed Bar, which had Vertue, and placed its North Pole's Armour about the Middle of the highest Bar, whose Middle I could reach to (keeping the Armour of the South Pole a little upon one Side of the Bars, just so far as I might be sure not to touch them with that End) and then immediately drew it from thence downward to the Bottom of the lowest Bar : After the same Manner placing the Armour of the South Pole on the Middle of the lowest Bar (and holding the armed North Pole on one Side, that it might not touch) I drew it upward to the Top of the highest Bar, whose Top I could reach. And if the End of any Bar was a little under that which it rested against, I used to put a sizeable Chip under it, that the Armour might not hitch in drawing it over the Places of their Contacts. I usually touched the Bars on all four of their Sides, then took out the lowest, and (letting the rest gently slide down to the Iron Pin) placed it at the Top, that those which were first at the Top might in their Turns take their Places in the Middle, and be well touched.

I commonly rested at the End of each Bar in drawing (as in the single Bar before mentioned, *Pag.* 325.) When I found those on the Board considerably stronger than my armed one, I took out that which I thought attracted best, and bound the Armour to it, putting the other in its Room. After several repeated Touchings, the biggest of them being xiij *Avoirdupois*,



would be suspended by its North Pole to the South Pole of one of the best of the others. They did not lift one another, or attract so well when their Ends were applied centrally, as when applied to one another (as is expressed in the Figure) near to their opposite Corners. The Line *m* in the End of each Bar represents the Manner I used to mark their intended South Poles. With one of these armed, I touched a small square Bar of Steel (placed betwixt two of the great ones) the Length whereof was 2.156 Inches, the Breadth of each Side 0.27 (or somewhat more than $\frac{1}{4}$ of an Inch) the Weight 3 v *Gr.* iv (*i. e.* 304 Grains) it would

lift afterwards an Iron $5\frac{1}{4}$ Inches long, weighing 3 iv 3 j 3 j or, 2000 *Gr.* 304 can be had 6.578 times in 2000. So it lifted above $6\frac{1}{2}$ times its own Weight. With this little Bar naked I touched a small Dial-Needle made of Steel (the Socket in the Middle was also Steel, and not Brass, as usual) I seasoned it very hard, and cleansed it well, and with much Care, not to break it, because so hard. It weighs not full 4 Grains, has lifted two prepared Six-penny Nails, one at each End, while it was held in an horizontal Posture with its South Pole towards the North. It also lifted a Key by the Bow, as it was held perpendicularly

dicularly with its South Pole downward, the Weight whereof was 3j 3ij Gr. xv good Weight (*i. e.* 115 Grains or better) Wherefore since the Needle weighed less than 4 Gr. which is the 29th Part of 116, we may reckon it lifted full 29 times its own Weight by the Force of one Pole, the Key having no permanent Vertue before.

I never saw this Communication of Magnetism outdone by the Loadstone itself, as it is commonly used; but what a good one would do, used as I did the Steel, I know not for want thereof, but doubt, unless Steel could be made better than it usually is, a stronger Degree of Attraction therein is scarce to be hoped for from the Use of the best of Loadstones.

I usually find the attractive Power in square Bars cut plain over transverse to their Lengths, to be strongest, not in the Middle of their Ends, but much nearer to their Corners or Sides, and to be greater at one Corner or Side than another; and this not only in such as are of touched Steel, but in Iron ones having no Polarity, but from their Position. The same I observed in round Bars, if their Ends are not convex.

In some of my large Steel Bars (as also in some of the round Bars) I found the North Pole strongest, in others the South. I know not the Cause thereof; for though I touched the weaker End twice so often as the stronger, it would still continue to be so, when the strongest had been well touched before. I imagine it must be owing to some Inequality of the Steel occasioned by the different Degree of Heat taken at the Forging; different Degree of Heat when the Smith desisted hammering; different Degree of Heat in making the Iron into Steel, or Quantity of what is used in doing it; Fineness of

the Iron whereof the Steel was made, some small Difference in Magnitude, or Difference in seasoning, it being almost impossible to make both Ends equally hard; but that both Ends of mine might be so, I had a Fire made long enough to heat their whole Length at one and the same Time.

I left several of the Bars on the Board whereon they were touched, and in the same Position to one another, as well as to the Earth, for some Months, to see whether they would lose any of their Vertue; but if they did, it was so little as I could not be sure thereof.

I also tried whether what I mentioned concerning Loadstones (*beginning at Page 303*) would hold in 5 or 6 Bars regularly touched and placed to one another in the same Manner; and found that at some of the Joinings it answered pretty well, but not so well at others, usually best at the two extrem Joints, and worse at the middle ones. When I held the Dial-Needle at a good Distance from the Bars (perhaps 6 or 8 Inches) the Attraction was more regular, and the different Poles of the two Bars at their Contact was not so easily discernable; but when I held it within 2 or 3 Inches Distance, both of the Poles discovered themselves more or less at every Joint. Perhaps the Cause may be the Want of a better Contact, the Ends of the Bars not being true Plains; or it may be partly owing to their conjunct Length (though I cannot see how that should cause it) or some Irregularity in the Vertue of each particular Bar. For it has been observed, that very oblong Iron, as Wire, is capable of having a North Pole in both Ends, and a South one in its Middle; or, as my round Bar before-

menti-

mentioned, several Polarities in no greater Length than about one Foot. My Bars were not made of *German*, but more ordinary Steel, of about 4 *d. per lb.*

I never yet tried the Experiment of weighing Pieces of oblong Steel just before, and presently after the Touch, but suppose (from Mr. *Norman's* Experiment, *New Attractive*, Chap. vi.) that my own Conjectures are right, *viz.* That oblong Steel of a convenient Length and Weight, perhaps 3 or 4 Feet, and 10 or 11 Ounces, may, if weighed with a very nice Beam, made of Iron or Steel, the Cords of the Scales being of a common Length, seem to lose a Grain or two of its Weight (more or less according to the Substance of the Beam, Shortness of the Cords, and Degree of Magnetism in the touched Steel). I say, seem to lose, because the touched Steel with one of its Poles attracts the Beam not just at the End thereof to which it is suspended, but there, and, more or less, all the Way between the said Point of Suspension and the Middle of the Beam. This must make it apparently (not really) to ponderate less, as is the Case of Stilliards, demonstrated by the Doctrine of the Lever: Also the other half of the Beam being somewhat attracted by the other Pole of the Steel, assists the Weights which are laid against the Steel, and encreaseth the Mistake, which is greater or less, according to the Posture of the Steel, whether (if horizontal) it is parallel or perpendicular to the Beam, or (if in an erect Posture) according to which Pole is upward. My Thoughts are, that Steel after the Touch (Allowance being made for what is rubbed off by touching, which I take to be insensible, if done on soft Armour) must, if in an horizontal Posture, necessarily draw

draw somewhat more Weight than before ; or if in an erect Posture in North Latitude with the South Pole downward more, and upwards less than in an horizontal Posture : But these Differences are so small as no Experiment I can think on will render sensible in the least Degree, because of the vast Distance between the Surface of the Earth and the attractive Point of the internal Magnet : For since Attraction and Repulsion are at the same Distance equal, I say the one Pole of a Bar of Steel 10 or 20 Feet long, directed toward the attractive Point of the Magnet, supposed at the Distance of but one or two Miles, is not sensibly nearer to it than the other (I mean in respect to Attraction) how much more insensible then must the far greater Distance of 2000 Miles render it, which is not so remote as Mr. *Whiston* (Longitude and Latitude found by the Dipping-Needle, *Pag.* 48. *Line* 12) supposes it to be. I cannot think fit to call the Point to which the Needle tends a respective Point, as Mr. *Norman* does, since his Experiments, *Chap.* VI. do not convince me (by reason of the Distance thereof from the Surface of the Earth) that it is not an attractive one. If therefore Steel after the Touch is ever found to weigh (with a Beam of Matter not magnetical, and in a Place at too great Distance from any Iron or Magnet to be sensibly affected thereby) either more or less than before, it must be occasioned by the Augmentation or Diminution of its Quantity of Matter by the Touch. The former seems impossible, because a Magnet loses no sensible Weight by having 10000 Pieces of Steel successively touched on its Armour ; nor is the latter probable, unless the Weight of the Magnet is encreased, or Part of the Substance
of

of the Steel ground off by touching: And if the Quantity of Steel is, by rubbing, diminished, the Lightness is not owing to its having Magnetism, but to its Defect of Matter. Before an Experiment of this Nature is made, the Piece of Steel should be well hardned, polished, and wiped very clean, and if warm by rubbing or handling, should be permitted to cool before it is weighed. Then being weighed with a Brads Beam, let it afterward be well touched on the soft Armour of a Magnet, then wiped clean, and permitted to cool, before it is weighed after the Touch. Care must also be taken that no Iron Bar, or other Magnet, be in the Window, or any other Part of the Room above, or that underneath, large enough to affect it, which a Magnet, the Brads of the Floor, or other Iron in the same Room, or about the Operator, such as a Key, Knife, Buckles, or the like, may more or less do, according to their Distance and Situation: And I have seen a Brad in the Floor make the End of a large horizontal Needle dip to it at the Distance of above an Inch.

Mr. *Whiston* in his said Book, *Pag.* 47, supposes the Surface of the Earth's central Magnet to be distant in Miles from the Surface of the Earth 3400, and accordingly, *Pag.* 48, computes the Semidiameter of the said Magnet to be about 575; both which Sums added, make the Semidiameter of the Earth to be about 3975 Miles; which is about 7 Miles less than Mr *Norwood* makes it by reckoning $69\frac{1}{2}$ Miles to a Degree, which multiplied by 360, makes 25020 in the whole Circumference, and the Radius (by *Van Ceulen's* Proportion of the Circumference to the Diameter) I find to be 3982.0566, &c. which 7 Miles is but a Trifle in 3975, or 3982.

I shall

I shall then suppose the Earth's Radius (in Miles) 3975, from whence I compute the Circumference $24975.6615,9603,8855$, &c. And one Degree $69.3768,3776,6774,5988,3$, &c.

Mr. *Whiston*, *Pag.* 53, says that the Northern magnetick Pole was then about $13\frac{1}{2}$ Degrees from the North Pole of the Earth: The Sine of which in natural Numbers is $233,4454$ to the Radius $1000,0000$.

1. As the Earth's Radius (in Miles) 3975, to the above-mentioned Sine of 13 Deg. 30 Min. $233,4454$. So the said Magnet's Radius 575 Miles to the Tabular Number $33.7688,3144,6540,8805,0311$, &c.

2. As the Tabular Radius $1000,0000$, to the said Tabular Number, so (in Miles) is the Earth's Radius to the Radius of the Parallel of $13\frac{1}{2}$ Gr. on the said Magnet's Surface: Or, so is the Earth's whole Circumference to the Circumference of the Central Magnet's said Parallel: Or, so is one Degree of the Earth's great Circle in Miles to one Degree of the said Parallel of $13\frac{1}{2}$ Gr. on the said Magnet's Surface $2.3427,7474,0840,2028,43$, &c.

The said Degree reduced into Feet, and into Inches, is,

In Feet and Parts $12369,8506,3163,6271,0156,59$, &c.

In Inches and Parts $148438.2075,7963,5252,1879,14$, &c. Which 2.3427 , &c. Miles the North magnetick Pole of the central Loadstone moves in somewhat less Time than 4 solar Minutes, *viz.* in about 4 Minutes by the diurnal apparent Motion of the fixed Stars) But for as much as the *Ratio* of the internal Magnet's Diameter to that of the Earth, is not probably calculated to Perfection, I shall proceed as if the said Pole of the Magnet moved the said Space perfectly in the Time of four Stellar Minutes. For

For want of a more convenient Instrument, I took a Whirligig of Wood, somewhat more than $\frac{1}{4}$ of an Inch thick, and in Diameter at least 1.8 Inch. It was turned truly round, and had in its Diameter nigh to, and equidistant from the Centre two Holes made, into which, as usual, was a Thread put, of about 40 Inches long, and about 20 when it was put in, and the two Ends tied together. I went with it to a Clock, whose Pendulum oscillated Seconds, and working the Whirligig strong enough to make its Returns, or Vibrations, keep equal Times with the Pendulum's Oscillations, I suddenly caught the Whirligig at the End of one Vibration before it began another, and then (untwisting the double Thread gradually with my Fingers) I told how many Turns or Revolves it had made in that one Vibration, and found the Thread untwisted with 58 Turns (which is but half the Number in one Vibration, because in the whole Vibration it was twisted the like Number of Turns the other Way) which doubled makes 116 Turns in each Vibration, and in one Second of Time. I computed the mean Velocity of the Circumference thereof in each Second of Time to be about 54 Feet 7 Inches 9645,4606, &c. Parts. By this it is plain, that a Globe (as well as a Wheel) of 6 Inches in Circumference, if truly centered, is easily capable of being kept in Motion on its Poles, so swift that its Æquator shall have the Velocity of 51 Feet 5410,4429,8, &c. Parts, by making 103,0820.8859, &c. Turns in one Second. This is the proper Velocity for such an Experiment, because it is nearly equal to that of the North magnetick Pole of the internal Loadstone along the Parallel of $13\frac{1}{2}$ Degrees from the Poles of its Rotation.

The Velocity of the said magnetical Pole of the internal Loadstone is, as above, in the Time of 4 Minutes, in Inches and Decimal Parts 148438.2075,7963,5252,1879,14.

And therefore in the Time of one Minute 37109.5518,9490,8813,0469,786, and in one Second 618.4925,3158,1813,5507,8297, which 618.4925, &c. Inches reduced to Feet and Decimal Parts, is 51.5410,4429,8, &c.

Suppose then a Terrella was made of just 6 Inches in Circumference $N \propto S n$ (*Vid. Fig. 1. Pl.*) contrived to gyrate on Poles $\propto n$ chosen in any two opposite Points of its magnetical *Æquator*, and the Axis of its Rotation $\propto n$ situated (as near as Art can do it) in the magnetical Line; for in this Posture of the Axis the magnetical Poles of the Terrella will be equally wrought on by the Earth's attractive Point all the Way as it is turned round, which can be in no other Posture whatsoever: For if the Axis of its Rotation makes the least Angle with the magnetical Line; as the Terrella is turned round, the magnetick Poles of it will be attracted and repelled more when on one Side than when on the other, which ought not to be, because it is probable it may have the same Effect which a large Magnet would have, if held within the Attraction, and consequently change the Polarity, as by a Touch, and not purely by the Gyration thereof.

The Circle $N \propto S n$ represents the Terrella in Circumference just 6 Inches (having both, or at least one, of its attractive Poles nicely marked) cemented, or bound with Thread fast to a cylindrical Vessel of Wood, or Brass pretty thin, that it may not be too heavy, with its Polarity $N S$ transverse to the Axis of the said

said cylindrical Vessel, whose Diameter on the Inside ought to be equal to that of the Terrella, and its Depth not less than the Radius. Or, if the Terrella is truly globular, instead of the cylindrical there may be a concave Vessel (represented by the pricked Line $x n w$) less than a Hemisphere, and its Diameter of Concavity somewhat less than that of the Terrella; so shall their Contact be wholly at the Brim of the Vessel, which will keep the Terrella central. And this may be better than a Cylinder, because lighter, and the most of its Parts nearer to the Axis of its Verticity. Either of these is to be centrally fixed to the Arbor $n m$, which, together with its Pivot r , should be made of Brass, and the Pivot Work in a Hole made fit for it in a Horse's Tooth, or some such Thing: The End of the Pivot should rest on the Bottom of the Hole, that it may move the easier. The Collar at P , in which the Arbor turns round, may be made of Tooth also, and both that and the Pivot aforesaid should be kept well oiled, or greased, to prevent their being heated by so rapid a Motion as is necessary, and so should also the other Axles. This is to be kept in Motion by a Gut-string (as the Spill of a Spinning-Turn is moved) tied pretty strait round the little Wheel at m , and the greater one at F , which String is represented by the pricked Line. And the Wheel F is turned after the same Manner, by a larger Gut-string round the Wheels t and Q , which must be strained very straight, that it may not slide on the Wheels. To prevent which Inconvenience, this String (and the other, if need be) may be rubbed well with powdered Rosin. I think a Gut-string round a great Wheel and lesser one, will work easier than the best of Clock-work, and without rattling

or jarring, which the latter, when in a rapid Motion, is subject to, and therefore I cannot approve of it, nor is the multiplying Power of the Wheels m F, being 10.3082, &c. so nearly to be calculated for a Wheel and Pinion ; but, if good Work, it may be allowed in the Wheels t Q, which move slower : But that I apprehend will needlessly encrease the Charge. The Diameter of each Wheel at the Bottom of the Trench, where the String touches it, is mentioned in the Draught. The whole may be made to turn with one's Hand, either with a Crank Q g in the Arbour of the Wheel Q, or with a Turner like that of a Grinding-stone R.

Mr. W——n, Page 78, makes one Revolution of the central Magnet, in respect of the Earth, to be not less than 1920 Years, which I have reduced to 701280 Days, to which I add 1920 Days, which makes the Sum 703200, being the Number of Revolutions, nearly, which the Earth and the said Magnet with it, makes in 1920 Years in respect of the fixed Stars. Now since the magnetick Pole of a Terrella 6 Inches in Circumference, centered as above is directed, and moving with the Velocity of 51 Feet 5410.4429, &c. Parts in the Time of one Second, by making 103.9820,8859, &c. Turns, moves equally rapid with that of the central Magnet, it may be expected that 703200 of its Revolutions should gradually translate each of its Poles one entire Circle, which 703200 Revolutions (at 103.0820, &c. *per* Second) will be finished in the Time of 6821 Seconds 7476,9272,396 Parts, or $1^h 53' 41'' 44''' 51'''' 41'''''$. Or,

351600 Revolut. translate it $\frac{1}{2}$ a Circle in 3410.8738,
4636,198'', or 0. 56' 50'' 52''' 25'''' 50'''''.

175800

175800 Revolut. translate it $\frac{1}{4}$ of a Circle in 1705.4319.
2318,099'', or 0.28' 25'' 26''' 12'''' 55'''''.

117200 Revolut. translate it $\frac{1}{5}$ of a Circle in 1136.9579.
4878,732'', or 0.18' 56'' 57''' 28'''' 36'''''.

If the Terrella's Circumference is more than 6 Inches, the magnetical Poles thereof may be placed so oblique to the Axis of the Cylinder, as that in turning round they may each of them describe a lesser Circle (or as it may be called a Parallel of Latitude) just 6 Inches in Circumference, and that will cause no Alteration in the Swiftneſs of the Motion of the Machine, which is to be moved as follows, *viz.* The Perſon that works it muſt keep his Eye on a Pendulum oſcillating Seconds, and turn the Crank (or Turner) once round at each Oſcillation, ſo ſhall the Number of the Terrella's Revolutions, and Celerity of the Motion of its Poles be as is above-mentioned.

But if the Terrella is larger than 6 Inches in Circumference, and its Polarity tranſverſe to the Axis of its Rotation, the Pendulum may be lengthened in Proportion of the Squares of their Circumferences, and the Crank muſt then make one Turn at each Oſcillation of the Pendulum ſo lengthened; and by that Means it will move with the ſame Celerity which was above propoſed; but then the 703200 Revolutions will not be finiſhed in leſs Time than 6821 Seconds (or rather Oſcillations) made by the lengthened Pendulum.

If by the keeping a Terrella in Motion in ſuch a Poſture, and with ſuch Celerity as is aforeſaid, the magnetical Poles thereof, in reſpect of the Terrella, remain immoveable, I think this is a plain Demonſtration that the central Magnet is looſe from the Earth,

Earth, and revolves within it a little slower, as is conjectured by several, and to me seems most probable.

But if the magnetical Poles, by such a Motion as is described, should in respect of the Terrella be translated with a Motion retrograde to that wherein it was kept by the Machine, I should think it possible for the diurnal Motion of the central Magnet to translate the Polarity thereof farther Westward by the Vertue of its own Effluvia, which are continually left a little behind, as it revolves on its Axle Eastward, and that the said Magnet is fixed to the Earth. But these Things seem uncertain.

However, I think it not impossible to reduce the Period of the Motion of the magnetical Pole, in respect of the Earth, to a tolerable Calculation in much less Time than an entire Revolution thereof, by measuring daily the Quantity thereof: For effecting which, I have thought on a new Way of making a Needle not above 6 Feet long, with some Engine-work to its Box, which, I believe, I can demonstrate will render it visible daily to a naked Eye, that the Variation is changed: But I have no Time at present to describe it, being but just able to finish this; but if it may be acceptable, shall readily communicate it on Notice.